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A Synopsis and Critique of Forecasts of Sockeye Salmon (*Oncorhynchus nerka*) Returning to Bristol Bay, Alaska, in 1987

by

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State of Alaska Steve Cowper, Governor

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ABSTRACT

A total of 16.5 million sockeye salmon *(Oncorhynchus nerka)* is expected to return to Bristol Bay, Alaska, in 1987 (80 percent confidence interval, 9.0 to 24.0 million). Although a total return of this size would be 53 percent less than the mean return for 1977-1986 (35.4 million), it would fall within the range of returns recorded during this time period (10.7 to 66.2 million). Returns to all river systems, except the Kvichak River, are predicted to be well above spawning escapement goals. The total commercial harvest is projected to be 9.3 million sockeye salmon (80 percent confidence interval, 3.2 to 16.0 million). About 42 percent of the total harvest is expected to be taken from the Egegik River District. Predictions for 1988-1989 based on spawner-recruit data indicated that the total number of sockeye salmon returning to Bristol Bay should begin to increase in 1988. Greatest returns for this period are expected to occur in 1989, mostly due to increased returns to the Kvichak River. Environmental indicators suggested that the extremely high level of sockeye salmon production which occurred during 1978-1985 may not be maintained over the next several years.

KEY WORDS: Forecast, sockeye salmon, Bristol Bay, spawner-recruit, environmental indicators

INTRODUCTION

The purpose of this report is to provide a final preseason forecast for sockeye salmon (*Oncorhynchus nerka*) returns to Bristol Bay, Alaska, in 1987 and to provide a long range outlook of returns for 1988 through 1990. Specific objectives are: (1) to present results of the various methods used to forecast sockeye salmon returns to Bristol Bay, (2) to document the performance of these various methods, (3) to indicate where actual returns are most likely to depart from preseason expectations, and (4) to present results from spawner-recruit models used to forecast returns for 1988-1990.

Until 1983 the annual preseason forecast used by the Alaska Department of Fish and Game (ADF&G) was calculated as the unweighted average of estimates obtained from models using either spawner-recruit, sibling, or smolt data. Forecasts obtained from this method, referred to as the ADF&G method, had a mean absolute percent error of 45 percent of the actual total run size for the last 26 years, 1961-1986. Other forecasting methods have also been examined, but while average performance of some of these has been better than the ADF&G method, year-to-year reliability has been inconsistent. Beginning in 1983 attempts were made to improve forecast reliability by pooling results from the ADF&G method with results from other methods (Eggers et al. 1983a and b, Fried and Yuen 1985 and 1986). Although only four years of data, 1983-1986, are available for comparison, results have been encouraging since these forecasts had a mean absolute percent error of only 14 percent. The 1987 preseason forecast is for a total return of 16.5 million sockeye salmon, based upon the weighted mean of the results of two independent methods: (1) ADF&G, and (2) Japanese Research Vessel Catch (JRVC).

METHODS

Age Designation

Adult ages were expressed according to modified European system designations (Koo 1962), wherein the number of annular (winter) scale checks formed in fresh and salt water are indicated to the left and right of a decimal point, respectively. Four age classes account for about 98 percent of total returns: 1.2, 2.2, 1.3, and 2.3, respectively. These four age classes were equivalent to the following Gilbert and Rich (1927) designations: 4_2, 5_3, 5_2, and 6_3. Gilbert and Rich (1927) designations are dated from the time of egg deposition and show both total age as well as the year of life in which seaward migration occurred (subscript).

Smolt ages were expressed as either age I or II, corresponding to sockeye salmon that migrated seaward in either their second or third year of life, respectively.

ADF&G Method Forecast

The ADF&G method forecast provided estimates of sockeye salmon return, by major age class, for nine river systems that account for about 98 percent of Bristol Bay sockeye salmon production. These systems are the Kvichak, Branch, Naknek, Egegik, Ugashik, Wood, Igushik, Nuyakuk, and Togiak Rivers. Forecasts for each system and age class were calculated by averaging results of several models which used either (1) spawner-recruit, (2) sibling, or (3) smolt data. Since 1986 only a single model (usually a linear regression model) has been used to calculate a forecast for each of the three data components (Fried and Yuen 1986). In some cases a result from a model was excluded from final calculations. The rationale for each exclusion can be found within the appropriate portion of the Results and Discussion section.

Predicted returns from spawner-recruit data were based on a linear form of the Ricker (1954) curve constructed for age-specific returns (Brannian et al. 1982):

$$\ln[R_{i,k,y}/E_{k,y}] = \ln[a] - bE_{k,y}, \text{ where}$$

$R_{i,k,y}$ = number of age i sockeye salmon returning to river system k from spawning during brood year y;

$E_{y,k}$ = total number of spawners in river system k during brood year y;

a and b = parameters which determine the y-axis intercept and slope of the line, respectively.

In cases where spawning escapements were much greater or much lower than any previously observed, predictions for age 1.2 sockeye salmon could not be calculated while predictions for the other age classes were calculated using the following relationships:

$$R_{5,k,y} = A_{4,k,y} / M_{4,k}, \text{ where}$$

$R_{5,k,y}$ = number of 1.3 and 2.2 sockeye salmon expected to return to river system k from brood year y;

$A_{4,k,y}$ = actual return of 1.2 sockeye salmon to system k from brood year y;

$M_{4,k}$ = mean proportion of 1.2 sockeye salmon within past returns to system k; and

$$R_{6,k,y} = A_{4\&5,k,y} / (1-M_{6,k}), \text{ where}$$

$R_{6,k,y}$ = number of 2.3 sockeye salmon expected to return to system k from brood year y;

$A_{4\&5,k,y}$ = actual return of 1.2, 2.2, and 1.3 sockeye salmon to system k from brood year y; and

$M_{6,k}$ = mean proportion of 2.3 sockeye salmon within past returns to system k.

Predicted returns from sibling (younger age classes from the same brood year) and smolt data were based upon linear regression models using natural logarithm transformed data, as suggested by Peterman (1982a and b):

$$\ln[R_{i,k,y}] = a + b \ln[S_{j,k,y}], \text{ where}$$

$R_{j,k,y}$ = number of age j (where j = i-1) sockeye salmon returning to system k from brood year y; or

$S_{j,k,y}$ = number of age j (where j = age I or II) smolt migrating from system k from brood year y.

Linear regression model forecasts using smolt data could only be made for Kvichak and Wood River systems, where smolt enumeration programs using sonar equipment were begun in 1971 (Russell 1972) and 1975 (Krasnowski 1976), respectively. Smolt enumeration programs were initiated on the Naknek (Huttunen 1984) and Egegik (Bue 1984) River systems in 1982 and on the Ugashik (Fried et al. 1987) and Nuyakuk (Minard and Frederickson 1987) River systems in 1983. Since sufficient data to fit regression models will not be available for these systems for several more years, forecasts were calculated using mean survival and maturity schedules for smolt from each of these systems:

$$R_{i,k,y} = S_{j,k,y} \times P_k \times Q_{i,j,k}, \text{ where}$$

P_k = mean proportion of the total smolt production from a brood year which survive to return to system k;

$Q_{i,j,k}$ = mean proportion of surviving age j smolt which return to system k as age i adults.

Japanese Research Vessel Catch Forecast

The Japanese Research Vessel Catch (JRVC) method forecast provided estimates of total returns of sockeye salmon which had remained at sea for either two (1.2 and 2.2) or three (1.3 and 2.3) years (hereafter referred to as two- and three-ocean age sockeye salmon, respectively). Estimates were made using data on catch per unit of effort (CPUE) and mean length of immature sockeye salmon captured by Japanese research vessels fishing south of the Aleutian Islands during July 1986 (Takagi and Ito 1986) along with Cold Bay, Alaska, air temperatures (Climatological Data Publications, U.S. Department of Commerce, National Climatic Data Center, Asheville, North Carolina) within a multiple linear regression model:

$$R_{o,z} = a + b_1\, G_{(o-1),(z-1)} + b_2\, L_{(o-1),(z-1)} + b_3\, C_{(z-1)\&(z-2)},$$

where $R_{o,z}$ = total number of ocean age group o sockeye salmon returning in year z;

$G_{(o-1),(z-1)}$ = geometric mean catch per unit of effort of ocean age group (o-1) in year (z-1);

$L_{(o-1),(z-1)}$ = mean fork length (mm) of ocean age group (o-1) in year (z-1);

$C_{(z-1)\&(z-2)}$ = mean June air temperature (^{o}F) at Cold Bay during year (z-1), or the sum of mean June air temperatures during years (z-1) and (z-2) for sockeye salmon remaining two or three years at sea, respectively.

Prior to 1985 these data were used to produce three separate forecasts: one based only upon geometric mean CPUE, another based only upon arithmetic mean CPUE, and a third based upon both mean fork length and mean June Cold Bay air temperatures (Eggers et al. 1983a and b). In 1985 use of arithmetic mean CPUE data was discontinued since we felt that geometric mean CPUE data would best meet regression assumptions of normality and homoscedacticity (Fried and Yuen 1985). We also combined temperature, length, and geometric mean CPUE data as independent variables within a single model, since the accuracy of this model, based on results of a "hindcasting" procedure, did not differ greatly than that of the two previously used models (Fried and Yuen 1986).

Pooling Forecast Results

Results from the ADF&G and JRVC methods were pooled by calculating the weighted mean of individual predictions:

$$F_o = \sum_{m=1}^{2} [F_{o,m} \times (1/SE_{o,m}^2)] \;/\; \sum_{m=1}^{2} (1/SE_{o,m}^2) \text{ , where}$$

F_o = weighted mean forecast of returns for ocean age group o;

$F_{o,m}$ = forecast of returns for ocean age group o from method m;

$SE_{o,m}^2$ = forecast standard error squared (variance) of returns for ocean age group o from method m.

$SE_{o,m}$ has been used by ADF&G staff since 1983 as the weighting factor for pooling results from different methods (Eggers et al. 1983a and b; Fried and Yuen 1985 and 1986). $SE_{o,m}$ is a measure of differences in past returns not accounted for by expected variations due to forecasting methods (Snedecor and Cochran 1969):

$$SE_{o,m} = \sqrt{1/(n-2) \sum_{i=1}^{n} (A_i - \hat{A}_i)^2} \text{ , where}$$

$\hat{A}$ = predicted return based on regression of past forecasts (independent variable) on actual returns (dependent variable).

Standard error estimates for each pooled ocean age forecast were calculated using a formula for samples of equal size (Snedecor and Cochran 1969):

$$SE_o = \sum_{m=1}^{n} SE_{o,m} / n \text{ , where}$$

SE_o = standard error estimate for pooled forecast of ocean age group o;

Finally, 80 percent confidence limits for each pooled ocean age group forecast was estimated using the following relationship:

$$80\% \text{ C.L.} = F_o \pm [t_{0.20[df]} \times SE_o] \text{ , where}$$

$t_{0.20[df]}$ = Student's t value with a probability of type I error of 0.20 and df degrees of freedom;

df = sum of degrees of freedom of variance terms = n(N-1),

where N = number of years examined for each of the n methods used in the pooled forecast.

Pooled two- and three-ocean age forecasts of total run size (including estimates of upper and lower 80 percent confidence limits) were apportioned among individual river systems by major age classes based upon proportions within the original Standard ADF&G forecast.

Long Range Outlook

Using spawner-recruit data, forecasts were also made for the years 1988, 1989, and 1990. To determine whether forecasts for these years were reasonable, past trends in sockeye salmon production and environmental conditions were examined for 1965-1986. Annual return per spawner values were calculated as the weighted sums of total escapements four, five, and six years prior to each annual return. The mean June air temperature associated with each annual return was calculated as the weighted mean of average June air temperatures recorded at Cold Bay, Alaska, one, two, and three years prior to each annual return. Deviations from the mean return per spawner value were calculated for actual returns in 1965-1986 and for forecasted returns in 1987-1990. Deviations from the mean Cold Bay air temperature in June associated with each annual return were calculated for 1965-1987. The correlation coefficient (Snedecor and Cochran 1969) between annual deviations from the mean return per spawner value and annual deviations from the mean June air temperature was calculated for 1965-1986 data, and a plot was made of all deviations for 1965-1990.

RESULTS AND DISCUSSION

Total Bristol Bay Forecast

The ADF&G and JRVC methods produced total Bristol Bay forecasts of 15.6 and 17.5 million sockeye salmon, respectively (Table 1). The JRVC method produced a greater two-ocean age group prediction (9.6 million, 55 percent of total) and a lower three-ocean age group prediction (7.9 million, 45 percent of total) than the ADF&G method (7.3 million, 47 percent of total, and 8.3 million, 53 percent of total, two- and three-ocean returns, respectively). Past performance of both methods, indicated by their standard errors, was similar (Table 2). The final weighted pooled forecast of total returns was 16.5 million sockeye salmon (Table 3), with an 80 percent confidence interval of 9.0 to 24.0 million. Total projected harvest was 9.6 million sockeye salmon (Table 3), with an 80 percent confidence interval of 3.2 to 16.0 million (assuming the proportion of the total run returning to individual systems remained constant for total run sizes within the 80 percent confidence interval).

A total return of 16.5 million sockeye salmon to Bristol Bay in 1987 would be 53 percent less than the mean return of 35.4 million for 1977-1986 (range, 10.7 to 66.2 million) and 37 percent less than the mean return of 26.0 million for 1967-1986 (range, 3.5 to 66.2 million).

River System Forecasts

Kvichak River

A total of 2.2 million sockeye salmon (80 percent confidence interval, 1.1 to 3.3 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total return to this system was 2.0 million sockeye salmon (Table 4). None of the individual components produced estimates that exceeded the escapement goal of 5.0 million sockeye salmon (Table 5). The largest total return estimate was produced by the spawner-recruit component (2.4 million), while the smallest was produced by the sibling component (1.5 million).

Sockeye salmon production within the Kvichak River system usually follows a 5-year abundance cycle (Mathisen and Poe 1981). A return of 2.2 million sockeye salmon to the Kvichak River system in 1987 would be similar to past returns observed during equivalent "low cycle" years (i.e., 1962, 1967, 1972, 1977, 1982), which have averaged 3.4 million (range, 1.8 to 5.6 million).

Age 1.2. The spawner-recruit and smolt components produced similar estimates of 1.066 and 0.991 million, respectively. The sibling estimate of 0.723 million was 32 percent less than the spawner-recruit estimate and 27 percent less than the smolt estimate. The ADF&G predicted return was 0.927 million and the final pooled predicted return was 1.054 million (80 percent confidence interval, 0.471 to 1.637 million).

Age 2.2. Widely divergent results were obtained from the three components. The spawner-recruit estimate of 0.802 million was almost three times greater than the sibling estimate of 0.280 million and almost 17 times greater than the smolt estimate of 0.048 million. The ADF&G method predicted return was 0.337 million and the final pooled predicted return was 0.429 million (80 percent confidence interval, 0.191 to 0.666 million).

Age 1.3. The spawner-recruit and sibling components produced similar estimates of 0.233 and 0.226 million, respectively. The smolt estimate of 0.741 million was over three times greater than either of the other two estimates. The ADF&G predicted return was 0.400 million and the final pooled predicted return was 0.393 million (80 percent confidence interval, 0.254 to 0.532 million).

Age 2.3. All components produced predictions less than 0.500 million. The smolt estimate of 0.482 million was 55 percent greater than the spawner-recruit estimate of 0.311 million and about two times greater than the sibling estimate of 0.227 million. The ADF&G method predicted return was 0.340 million and the final pooled predicted return was 0.334 million (80 percent confidence interval, 0.216 to 0.453 million).

Branch River

A total of 0.3 million sockeye salmon (80 percent confidence interval, 0.2 to 0.5 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was also about 0.3 million sockeye salmon (Table 4). Only spawner-recruit and sibling information were available for this system (Table 6).

A total return of 0.3 million sockeye salmon to the Branch River in 1987 would be 40 percent less than the mean return of 0.5 million for 1977-1986 (range, 0.2 to 0.9 million) and 25 percent less than the mean return of 0.4 million for 1967-1986 (range, 0.1 to 0.9 million).

Age 1.2. The sibling estimate of 0.095 million was 30 percent greater than the spawner-recruit estimate of 0.073. The ADF&G predicted return was 0.084 million and the final pooled predicted return was 0.095 million (80 percent confidence interval, 0.043 to 0.148 million).

Age 2.2. A prediction based upon sibling data could not be made since no age 2.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 2.2 forecast for this system was based only upon results from the spawner-recruit component. The ADF&G predicted return was 0.056 million and the final pooled predicted return was 0.064 million (80 percent confidence interval, 0.028 to 0.099 million).

Age 1.3. The spawner-recruit and sibling components produced similar return estimates of 0.142 and 0.128 million, respectively. The ADF&G predicted return was 0.135 million and the final pooled predicted return was 0.133 million (80 percent confidence interval, 0.086 to 0.180 million).

Age 2.3. The sibling estimate of 0.020 million was almost three times greater than the spawner-recruit estimate of 0.007 million. Both the ADF&G and the final pooled predicted returns were 0.014 million (80 percent confidence interval, 0.009 to 0.019 million).

Naknek River

A total of 2.1 million sockeye salmon (80 percent confidence interval, 1.2 to 3.0 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was 2.0 million sockeye salmon (Table 4). Sibling data was only available for three-ocean return predictions. Predictions from the smolt component were less than those from the spawner-recruit component for two-ocean returns and generally greater than those from both the spawner-recruit and sibling components for three-ocean returns (Table 7).

A total return of 2.1 million sockeye salmon to the Naknek River in 1987 would be 49 percent less than the mean return of 4.1 million for 1977-1986 (range, 2.0 to 7.9 million) and 32 percent less than the mean return of 3.1 million for 1967-1986 (range, 0.7 to 7.9 million).

Age 1.2. A prediction based upon sibling data could not be made since no age 1.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 1.2 forecast for this system was based only upon results from the spawner-recruit and smolt components. The spawner-recruit estimate of 0.340 million was over four times greater than the smolt estimate of 0.076 million. The ADF&G predicted return was 0.208 million and the final pooled predicted return was 0.236 million (80 percent confidence interval, 0.106 to 0.367 million).

Age 2.2. A prediction based upon sibling data could not be made since no age 2.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 2.2 forecast for this system was based only upon results from the spawner-recruit and smolt components. Smolt data indicated a return of 0.342 million which was 37 percent less than the spawner-recruit estimate of 0.544. The ADF&G predicted return was 0.443 million and the final pooled predicted return was 0.504 million (80 percent confidence interval, 0.225 to 0.782 million).

Age 1.3. The smolt estimate of 0.899 million was only 17 percent greater than the spawner-recruit estimate of 0.766 million but was 88 percent greater than the sibling estimate of 0.479 million. The ADF&G predicted return was 0.715 million and the final pooled predicted return was 0.703 million (80 percent confidence interval, 0.455 to 0.952 million).

Age 2.3. The sibling component estimate of 0.513 was almost 30 percent less than either the spawner-recruit estimate of 0.723 million or the smolt estimate of 0.703 million. The ADF&G predicted return was 0.646 million and the final pooled predicted return was 0.635 million (80 percent confidence interval, 0.411 to 0.860 million).

Egegik River

A total of 5.0 million sockeye salmon (80 percent confidence interval, 2.6 to 7.3 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was 4.6 million sockeye salmon (Table 4). Results from the spawner-recruit component (2.8 million) were much less than those from either the sibling (5.1 million) or smolt (6.1 million) components for all major age classes except age 2.2 returns (Table 8).

A total return of 5.0 million sockeye salmon to the Egegik River in 1987 would be similar to the mean return of 5.2 million for 1977-1986 (range, 2.2 to 9.0 million), but 40 percent greater than the mean return of 3.5 million for 1967-1986 (range, 0.8 to 9.0 million).

Age 1.2. Widely divergent results were obtained from the three components. The smolt estimate of 2.413 million was almost four times greater than the sibling estimate of 0.675 million and 16 times greater than the spawner-recruit estimate of 0.150 million. The ADF&G predicted return was 1.079 million and the final pooled predicted return was 1.227 million (80 percent confidence interval, 0.548 to 1.906 million).

Age 2.2. The sibling estimate of 2.197 million was 32 percent greater than the spawner-recruit estimate of 1.662 million and 97 percent greater than the smolt estimate of 1.115 million. The ADF&G predicted return was 1.658 million and the final pooled predicted return 1.885 million (80 percent confidence interval, 0.842 to 2.928 million).

Age 1.3. The smolt estimate of 1.479 million was 37 percent greater than the sibling estimate of 1.080 million and almost six times greater than the spawner-recruit estimate of 0.261 million. The ADF&G predicted return was 0.940 million and the final pooled predicted return was 0.925 million (80 percent confidence interval, 0.598 to 1.251 million).

Age 2.3. The smolt estimate of 1.048 million was only slightly greater than the sibling estimate of 1.105 million, but 53 percent greater than the spawner-recruit estimate of 0.686 million. The ADF&G predicted return was 0.946 million and the final pooled predicted return was 0.930 million (80 percent confidence interval, 0.602 to 1.259 million).

Ugashik River

A total of 3.2 million sockeye salmon (80 percent confidence interval, 1.9 to 4.5 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was 3.0 million sockeye salmon (Table 4). Predictions from the smolt component were much greater than those from either the spawner-recruit or sibling components for all age classes except 2.3 returns (Table 9).

A total return of 3.2 million sockeye salmon to the Ugashik River in 1987 would be only 14 percent less than the mean return of 3.6 million for

1977-1986 (range, 0.1 to 7.7 million), but 55 percent greater than the mean return of 2.0 million for 1967-1986 (range, 0.1 to 7.7 million).

Age 1.2. A prediction based upon sibling data could not be made since no 1.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 1.2 forecast for this system was based only upon results from the spawner-recruit and smolt components. Spawner-recruit and smolt components produced similar estimates of 0.381 and 0.373 million, respectively. The ADF&G predicted return was 0.377 million and the final pooled predicted return was 0.429 million (80 percent confidence interval, 0.191 to 0.666 million).

Age 2.2. The smolt estimate of 1.214 million was 39 percent greater than the spawner-recruit estimate of 0.874 million and about seven times greater than the sibling estimate of 0.174 million. The ADF&G predicted return was 0.754 million and the final pooled predicted return was 0.857 million (80 percent confidence interval, 0.383 to 1.332 million).

Age 1.3. The smolt estimate of 3.065 million was almost eight times greater than either the spawner-recruit estimate of 0.408 million or the sibling estimate of 0.384 million. A return of 3.065 million would be about 20 percent greater than the record return of 2.592 million which occurred in 1986. The ADF&G predicted return was 1.286 million and the final pooled predicted return was 1.265 million (80 percent confidence interval, 0.818 to 1.712 million).

Age 2.3. The smolt estimate of 1.099 million was more than two times greater than the sibling estimate of 0.482 million and about four times greater than the spawner-recruit estimate of 0.276 million. The ADF&G predicted return was 0.619 million and the final pooled predicted return was 0.609 million (80 percent confidence interval, 0.393 to 0.824 million). A return of 0.609 million would be the second largest ever recorded for this system. The largest return, 0.838 million, occurred in 1986.

Wood River

A total of 2.0 million sockeye salmon (80 percent confidence interval, 1.1 to 2.9 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was 1.9 million sockeye salmon (Table 4). Predictions from the spawner-recruit (2.1 million) and smolt (2.0 million) components were generally greater than those from the sibling component (1.5 million) for most age classes. (Table 10).

A total return of 2.0 million sockeye salmon to the Wood River in 1987 would be 40 percent less than the mean return of 3.3 million for 1977-1986 (range, 0.9 to 4.9 million), and 17 percent less than the mean return of 2.4 million for 1967-1986 (range, 0.7 to 4.9 million).

Age 1.2. The spawner-recruit estimate of 1.018 million was 56 percent greater than the sibling estimate of 0.653 million and 41 percent greater then the smolt estimate of 0.724 million. The ADF&G predicted return was

0.798 million and the final pooled predicted return was 0.907 million (80 percent confidence interval, 0.405 to 1.409 million).

Age 2.2. Spawner-recruit, sibling and smolt components produced similar estimates of 0.118, 0.115, and 0.121 million sockeye salmon, respectively. The ADF&G predicted return was 0.118 million and the final pooled predicted return was 0.134 million (80 percent confidence interval, 0.060 to 0.208 million).

Age 1.3. The smolt estimate of 1.164 million was 28 percent greater than the spawner-recruit estimate of 0.908 million and 80 percent greater than the sibling estimate of 0.648 million. The ADF&G predicted return was 0.907 million and the final pooled predicted return was 0.892 million (80 percent confidence interval, 0.577 to 1.207 million). A return of 0.892 million would be below the range of 1.1 to 2.6 million (mean, 1.7 million) observed for this age class during the past nine years, 1978-1986.

Age 2.3. The smolt estimate was not used since age-II smolt production from the 1981 brood year was the lowest ever recorded (previous record low count was 1.932 million from the 1977 brood year) and, therefore, not within the data range used for the predictive model. The spawner-recruit and sibling estimates were 0.084 and 0.050 million, respectively. The ADF&G predicted return was 0.067 million and the final pooled predicted return was 0.066 million (80 percent confidence interval, 0.043 to 0.089 million).

Igushik River

A total of 0.5 million sockeye salmon (80 percent confidence interval, 0.3 to 0.7 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was also 0.5 million sockeye salmon (Table 4). Only spawner-recruit and sibling data were available for this system (Table 11). Spawner-recruit component predictions were slightly less than sibling predictions for two-ocean returns but much greater than sibling predictions for three-ocean returns.

A total return of 0.5 million sockeye salmon to the Igushik River in 1987 would be 64 percent less than the mean return of 1.4 million for 1977-1986 (range, 0.2 to 3.2 million), and 45 percent less than the mean return of 0.9 million for 1967-1986 (range, 0.1 to 3.2 million).

Age 1.2. A prediction based upon sibling data could not be made since no age 1.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 1.2 forecast for this system was based only upon results from the spawner-recruit component which produced an ADF&G predicted return of 0.079 million sockeye salmon and a final pooled predicted return of 0.090 million (80 percent confidence interval, 0.040 to 0.140 million).

Age 2.2. Spawner-recruit and sibling components produced return estimates of 0.049 and 0.056 million sockeye salmon, respectively. The ADF&G predicted return was 0.053 million sockeye salmon and the final pooled predicted return was 0.060 million (80 percent confidence interval, 0.027 to 0.094 million).

Age 1.3. The spawner-recruit estimate of 0.475 million was more than two times greater than the sibling estimate of 0.223. The ADF&G predicted return was 0.349 million and the final pooled predicted return was 0.343 million (80 percent confidence interval, 0.222 to 0.465 million).

Age 2.3. The spawner-recruit estimate of 0.050 million was more than four times greater than the sibling estimate of 0.012 million. The ADF&G predicted return was 0.031 million and the final pooled predicted return was 0.030 million (80 percent confidence interval, 0.020 to 0.041 million). The return of 0.004 million age 2.2 sockeye salmon in 1986 was the second lowest ever recorded for this system. The lowest return of age 2.2 sockeye salmon ever recorded was 0.003 million in 1973.

Nuyakuk River

A total of 0.8 million sockeye salmon (80 percent confidence interval, 0.5 to 1.2 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was also 0.8 million sockeye salmon (Table 4). Sibling component estimates could not be made for two-ocean age class returns (Table 12). Smolt component results were greater than spawner-recruit results for two-ocean returns, but less than both spawner-recruit and sibling results for three-ocean returns

A total return of 0.8 million sockeye salmon to the Nuyakuk River in 1987 would be 60 percent less than the mean return of 2.0 million for 1977-1986 (range, 0.4 to 5.1 million), and 33 percent less than the mean return of 1.2 million for 1967-1986 (range, 0.1 to 5.1 million).

Age 1.2. A prediction based upon sibling data could not be made since no age 1.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 1.2 forecast for this system was only based upon results from the spawner-recruit and smolt components. The smolt estimate of 0.237 million was about twice as great as the spawner-recruit estimate of 0.119 million. The ADF&G predicted return was 0.178 million and the final pooled predicted return was 0.202 million (80 percent confidence interval, 0.090 to 0.314 million).

Age 2.2. A prediction based upon sibling data could not be made since no age 2.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 2.2 forecast for this system was only based upon results from the spawner-recruit and smolt components. The spawner-recruit and smolt estimates were 0.038 and 0.045 million, respectively. The ADF&G predicted return was 0.042 million and the final pooled predicted return was 0.048 million (80 percent confidence interval, 0.021 to 0.074 million).

Age 1.3. The spawner-recruit estimate of 0.971 million was more than twice as great as the sibling estimate of 0.406 million and the smolt estimate of 0.374 million. The ADF&G predicted return was 0.584 million and the final pooled predicted return was 0.574 million (80 percent confidence interval, 0.371 to 0.777 million).

Age 2.3. The 1981 spawning escapement of 0.834 million sockeye salmon was the second highest ever recorded, only exceed by the 1980 escapement of 3.026 million, and produced a return estimate of 0.060 million. Sibling and smolt data indicated returns of only 0.008 and 0.001 million, respectively, about eight and sixty times less than the prediction from the spawner-recruit component. The ADF&G and the final pooled predicted returns were both 0.023 million (80 percent confidence interval, 0.015 to 0.031 million).

Togiak River

A total of 0.4 million sockeye salmon (80 percent confidence interval, 0.2 to 0.6 million) was forecasted to return to this system based upon the pooled results of the ADF&G and JRVC methods (Table 3). The ADF&G method prediction for total returns to this system was also about 4.0 million sockeye salmon (Table 4). Only spawner-recruit and sibling data were available for this system (Table 13). Spawner-recruit component predictions were greater than sibling predictions for all age classes.

A total return of 0.4 million sockeye salmon to the Togiak River in 1987 would be 43 percent less than the mean return of 0.7 million for 1977-1986 (range, 0.3 to 1.2 million), and 20 percent less than the mean return of 0.5 million for 1967-1986 (range, 0.1 to 1.2 million).

Age 1.2. Spawner-recruit and sibling components produced return estimates of 0.096 and 0.083 million, respectively. The ADF&G predicted return was 0.090 million and the final pooled predicted return was 0.102 million (80 percent confidence interval, 0.046 to 0.159 million).

Age 2.2. A prediction based upon sibling data could not be made since no age 2.1 sockeye salmon were obtained from samples collected in 1986. Therefore, the age 2.2 forecast for this system was only based upon results from the spawner-recruit component. The 1982 spawning escapement was the fourth highest ever recorded and produced an ADF&G predicted return of 0.025 million and a final pooled predicted return of 0.028 million (80 percent confidence interval, 0.013 to 0.044 million).

Age 1.3. The spawner-recruit estimate of 0.324 million was 54 percent greater than the sibling estimate of 0.210 million. The ADF&G predicted return was 0.267 million and the final pooled predicted return was 0.263 million (80 percent confidence interval, 0.170 to 0.355 million).

Age 2.3. The 1981 spawning escapement of 0.307 million was the second highest ever recorded, and was exceeded only by the 1980 escapement of 0.526 million. (An escapement of 0.306 million occurred in 1978.) This produced a spawner-recruit estimate of 0.018 million, which was almost two times greater than the sibling estimate of 0.010 million. The ADF&G and final pooled predicted return estimates were both 0.014 million (80 percent confidence interval, 0.009 to 0.019 million).

Pooled Deviations from Forecast

The total forecast based upon the ADF&G method was only about 11 percent less than that based upon the JRVC method (Table 1). The greatest difference between the two methods was found in two-ocean return predictions (Table 2). The ADF&G estimate for two-ocean returns was about 24 percent less than that of the JRVC estimate, while the ADF&G estimate for three-ocean returns was six percent greater than that of the JRVC estimate. Since past performance of the ADF&G method has been somewhat better than that of the JRVC method (Table 2), the ocean age composition of the weighted mean most closely resembled that of the ADF&G estimate (Table 14). Inconsistencies between the two methods, as well as among component models within the ADF&G method, indicate that the most likely deviations from the pooled forecast would be: (1) greater than predicted two-ocean returns to the Kvichak and Naknek River systems, (2) less than predicted two-ocean returns to the Egegik and Ugashik River systems, (3) greater than predicted three-ocean returns to the Wood River system, and (4) less than predicted three-ocean returns to the Ugashik, Nuyakuk and Togiak River systems (Table 15).

Long Range Outlook

Forecasts made for the years 1988, 1989, and 1990 using spawner-recruit date, when compared to the spawner-recruit component of the 1987 forecast, suggested that the total number of sockeye salmon returning to Bristol Bay will begin to increase after 1987 (Table 16). The greatest total return for these years is expected to occur in 1989, mostly due to a greatly increased return to the Kvichak River. Returns to all other systems should be relatively stable over these years.

While annual predictions for 1987-1990 based on spawner-recruit data were less than the mean annual return for 1977-1986 (35.4 million), they were very similar to the mean annual return for 1967-1976 (16.6 million). A decline in sockeye salmon production to 1967-1976 levels over the next four years would not be unusual, since a significant ($P < 0.01$), positive correlation ($r = 0.705$) between sockeye salmon production and general environmental conditions has been observed since 1965 (Figure 1). Spawning escapements producing returns expected over the next four years were generally less than those which produced large returns for 1983-1986, but were very similar to those which produced large returns for 1979-1982. However, general environmental conditions, as indicated by mean Cold Bay air temperatures in June, may become less favorable to sockeye salmon production over the next four years than they have been since 1978. Weighted mean air temperatures during the three years each brood spent at sea were generally warmer than average for sockeye salmon that returned to spawn during the period 1978-1985, but were cooler than average for sockeye salmon that returned in 1986 and that will return in 1987. If below average air temperatures persist until at least 1989, survival of sockeye salmon returning to spawn during 1987-1990 may be adversely affected. Although forecasts for the years 1988-1990 will be modified as more information becomes available, it is likely that the extremely high levels of sockeye salmon production which occurred during 1978-1985 may not be maintained over the next several years.

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Table 1. Comparisons of forecasts of sockeye salmon returns to Bristol Bay, Alaska, 1961-1987, based on two independent methods and their weighted mean.

	Forecast (millions)			Actual Return (millions)	
Year	ADF&G[a]	JRVC[b]	Weighted[c] Mean	Inshore	Total[d]
1961	43.6			18.1	24.5
1962	19.6			10.4	11.7
1963	8.6			6.9	8.0
1964	17.4			10.9	11.5
1965	27.8			53.1	60.8
1966	31.3			17.5	20.0
1967	13.7			10.3	11.5
1968	10.4			8.0	9.4
1969	21.3			19.0	21.9
1970	55.8			39.4	45.0
1971	15.2			15.8	18.3
1972	9.7			5.4	7.2
1973	6.2			2.4	3.5
1974	5.0			10.9	11.5
1975	12.0			24.2	25.8
1976	12.0			11.5	12.8
1977	8.4	26.2		9.7	10.7
1978	11.5	2.9		19.8	20.8
1979	22.7	9.1		39.8	40.9
1980	54.5	49.6		62.4	66.2
1981	26.7	17.0		34.5	37.1
1982	34.6	15.0		22.1	24.7
1983	27.1	53.9	33.4	45.8	48.0
1984	41.5	13.8	31.1	41.0	42.6
1985	25.3	44.2	35.0	36.6	38.5
1986	23.7	19.1	22.5	23.7	24.4
1987	15.6	17.5	16.5	?	?

[a]Published ADF&G forecasts for past years.

[b]Hindcasted JRVC forecast estimates (using data only prior to the year for which estimate was made).

[c]Published pooled forecast for past years calculated as mean, weighted by inverse of variance, of several methods (1983: ADF&G, Japanese Gill Net CPUE, and Escapement-Temperature Model; 1984: ADF&G, Japanese Gill Net CPUE, Temperature-Length Model, Escapement-Temperature Model, and Bay-wide Sibling Returns; 1985 and 1986: ADF&G and JRVC).

[d]Included foreign high seas and domestic False Pass-Shumagin Islands catch estimates.

Table 2. Comparisons of forecasts of two- and three-ocean sockeye salmon returns to Bristol Bay, Alaska, 1977 - 1987, based on the ADF&G and JRVC methods.

	Forecast (millions)				Actual[c] Return (millions)	
	ADF&G[a]		JRVC[b]			
Year	Two-ocean	Three-ocean	Two-ocean	Three-ocean	Two-ocean	Three-ocean
1977	4.1	4.3	0.3	25.9	4.9	5.7
1978	7.8	3.7	2.4	0.5	12.4	7.8
1979	17.0	5.7	0.5	8.6	32.9	7.7
1980	41.2	13.4	42.3	7.3	49.2	16.6
1981	12.9	13.8	9.0	8.0	17.0	20.0
1982	22.0	12.6	4.4	10.6	6.1	18.3
1983	18.8	8.3	30.6	8.3	39.1	8.5
1984	22.7	18.8	4.6	9.2	29.5	12.9
1985	12.4	12.9	34.5	9.7	22.9	15.4
1986	11.9	11.8	11.8	5.4	10.2	14.0
1987	7.3	8.3	9.6	7.9	?	?
Regression (forecast versus actual) standard error						
(1977-1986):	10.5	3.4	11.8	5.1		

[a]Published forecasts for past years.

[b]Hindcasted estimates (using data only prior to the year for which estimate was made).

[c]Included foreign high seas and domestic False Pass - Shumagin Islands catch estimates.

Table 3. Forecasted returns of major age classes of sockeye salmon to Bristol Bay, Alaska, river systems and commercial fishing districts in 1987[a].

District: System	Numbers of sockeye salmon (thousands) Forecasted Return by Age Class 1.2	2.2	1.3	2.3	Total	Spawning Goal	Harvest
Naknek-Kvichak:							
Kvichak	1,054	429	393	334	2,210	5,000	0
Branch	95	64	133	14	306	185	121
Naknek	236	504	703	635	2,078	1,000	1,078
Total	1,385	997	1,229	983	4,594		1,199
Egegik	1,227	1,885	925	930	4,967	1,000	3,967
Ugashik	429	857	1,265	609	3,160	700	2,460
Nushagak:							
Wood	907	134	892	66	1,999	1,000	999
Igushik	90	60	343	30	523	200	323
Nuyakuk	202	48	574	23	847	500	347
Total	1,199	242	1,809	119	3,369		1,669
Togiak	102	28	263	14	407	150	257
Total Bristol Bay [b]	4,342	4,009	5,491	2,655	16,497		9,552

[a]Predictions are weighted mean results of the ADF&G and JRVC methods.

[b]Sockeye salmon of minor age classes and systems not considered within forecast calculations may increase the total return by one to two percent.

Table 4. Summary of results of ADF&G methods, showing estimated returns of sockeye salmon to Bristol Bay, Alaska, river systems and commercial fishing districts in 1987[a].

District: System	Numbers of sockeye salmon by age class (thousands)				
	1.2	2.2	1.3	2.3	Total
Naknek-Kvichak District:					
Kvichak	927	377	400	340	2,044
Branch	84	56	135	14	289
Naknek	208	443	715	646	2,012
Total	1,219	876	1,250	1,000	4,345
Egegik District	1,079	1,658	940	946	4,623
Ugashik District	377	754	1,286	619	3,036
Nushagak District:					
Wood River	798	118	907	67	1,890
Igushik River	79	53	349	31	512
Nuyakuk River	178	42	584	23	827
Total	1,055	213	1,840	121	3,229
Togiak District	90	25	267	14	396
Total Bristol Bay[b]	3,820	3,526	5,583	2,700	15,629

[a]See Table 3 for actual preseason forecast based on pooled results of ADF&G and JRVC methods.

[b]Sockeye salmon of minor age classes and systems not considered within forecast calculations may increase the total return by one or two percent.

Table 5. Forecasted returns of major age classes of sockeye salmon to the Kvichak River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit, sibling returns, and smolt components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	3,569	1,066	0.05	28
2.2	1,134	802	0.03	27
1.3	1,134	233	0.21	27
2.3	1,754	311	0.13	26
	Total	2,412		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	1	723	0.42	13
2.2	1	280	0.68	13
1.3	441	226	0.77	12
2.3	911	227	0.58	12
	Total	1,456		

Smolt Component

Age Class	Smolt Production (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	23,590	991	0.53	13
2.2	1,937	48	0.85	13
1.3	51,893	741	0.86	12
2.3	37,595	482	0.33	12
	Total	2,262		

[a]Based on results of linear regression models.

Table 6. Forecasted returns of major age classes of sockeye salmon to the Branch River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit and sibling returns components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	96	73	0.07	28
2.2	239	56	0.06	25
1.3	239	142	0.12	27
2.3	82	7	0.06	25
	Total	278		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	<1	95	0.17	18
1.3	170	128	0.38	30
2.3	51	20	0.32	25
	Total	243		

[a]Based on results of linear regression models.

Table 7. Forecasted returns of major age classes of sockeye salmon to the Naknek River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit, sibling returns, and smolt components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	888	340	0.09	28
2.2	1,155	544	0.14	27
1.3	1,155	766	0.05	27
2.3	1,796	723	0.25	26
	Total	2,373		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.3	183	479	0.43	30
2.3	462	513	0.20	30
	Total	992		

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival	Proportion Maturing	Predicted Return (thousands)
1.2	6,307	0.04	0.30	76
2.2	13,370	0.04	0.64	342
1.3	32,140	0.04	0.70	899
2.3	48,825	0.04	0.36	703
			Total	2,020

[a]Based on results of linear regression models.

Table 8. Forecasted returns of major age classes of sockeye salmon to the Egegik River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit, sibling returns, and smolt components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	792	150	0.03	28
2.2	1,034	1,662	<0.01	27
1.3	1,034	261	0.07	27
2.3	694	686	0.14	26
	Total	2,759		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	2	675	0.40	11
2.2	11	2,197	0.63	23
1.3	1,004	1,080	0.75	30
2.3	3,299	1,105	0.40	30
	Total	5,057		

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival	Proportion Maturing	Predicted Return (thousands)
1.2	54,586	0.13	0.34	2,413
2.2	11,435	0.13	0.75	1,115
1.3	17,234	0.13	0.66	1,479
2.3	32,236	0.13	0.25	1,048
			Total	6,055

[a]Based on results of linear regression models.

Table 9. Forecasted returns of major age classes of sockeye salmon to the Ugashik River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit, sibling returns, and smolt components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	1,000	381	<0.01	28
2.2	1,157	874	0.01	27
1.3	1,157	408	<0.01	27
2.3	1,326	276	0.04	26
	Total	1,939		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
2.2	1	174	0.67	19
1.3	413	384	0.88	30
2.3	2,197	482	0.67	30
	Total	1,040		

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival	Proportion Maturing	Predicted Return (thousands)
1.2	12,694	0.07	0.42	373
2.2	21,408	0.07	0.81	1,214
1.3	75,491	0.07	0.58	3,065
2.3	82,657	0.07	0.19	1,099
			Total	5,751

[a]Based on results of linear regression models.

Table 10. Forecasted returns of major age classes of sockeye salmon to the Wood River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit, sibling returns, and smolt components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	1,360	1,018	0.05	28
2.2	976	118	0.04	27
1.3	976	908	0.26	27
2.3	1,233	84	0.30	24
	Total	2,128		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	1	653	0.36	19
2.2	<1	115	0.43	12
1.3	498	648	0.14	30
2.3	82	50	0.35	28
	Total	1,466		

Smolt Component

Age Class	Smolt Production (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	31,950	724	0.61	10
2.2	4,690	121	0.34	10
1.3	22,330	1,164	0.41	9
2.3	1,380[b]	25	0.18	9
	Total	2,034		

[a]Based on results of linear regression models.

[b]Not used in forecast, since smolt count was out of range of data used in predictive model. Previous record low count was 1,932 million age-II smolt in 1980 migration.

Table 11. Forecasted returns of major age classes of sockeye salmon to the Igushik River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit and sibling returns components of the ADF&G method.

		Spawner-Recruit Component		
Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	180	79	0.27	28
2.2	423	49	0.23	27
1.3	423	475	0.32	27
2.3	591	50	0.30	26
	Total	653		

		Sibling Component		
Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
2.2	<1	56	0.55	5
1.3	52	223	0.18	30
2.3	4[b]	12	0.36	30
	Total	291		

[a]Based on results of linear regression models.

[b]Second lowest return of 2.2 sockeye salmon on record for this system (lowest return was 0.003 million in 1973).

Table 12. Forecasted returns of major age classes of sockeye salmon to the Nuyakuk River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit, sibling returns, and smolt components of the ADF&G method.

Spawner-Recruit Component

Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	318	119	0.11	28
2.2	537	38	0.02	26
1.3	537	971	0.15	27
2.3	834[b]	60	<0.01	24
	Total	1,188		

Sibling Component

Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.3	98	406	0.43	30
2.3	5	8	0.46	26
	Total	414		

Smolt Component

Age Class	Smolt Production (thousands)	Estimated Survival	Proportion Maturing	Predicted Return (thousands)
1.2	22,597	0.07	0.15	237
2.2	769	0.07	0.84	45
1.3	6,294	0.07	0.85	374
2.3	90	0.07	0.16	1
			Total	657

[a]Based on results of linear regression models.

[b]Second greatest spawning escapement ever recorded (greatest escapement was 3,026 million in 1980).

Table 13. Forecasted returns of major age classes of sockeye salmon to the Togiak River system, Bristol Bay, Alaska, in 1987 based on spawner-recruit and sibling returns components of the ADF&G method.

		Spawner-Recruit Component		
Age Class	Parental Spawning Escapement (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	212	96	0.29	28
2.2	288	25	0.31	27
1.3	288	324	0.18	27
2.3	307	18	0.39	26
	Total	463		

		Sibling Component		
Age Class	Sibling Return in 1986 (thousands)	Predicted[a] Return (thousands)	Coefficient of Determination (r^2)	Sample Size
1.2	<1	83	0.01	11
1.3	95	210	0.19	29
2.3	6	10	0.28	29
	Total	303		

[a]Based on results of linear regression models.

Table 14. Comparison of age composition of total forecasted returns of major age classes of sockeye salmon to Bristol Bay, Alaska, in 1987.

	Forecast (millions)		
Age Class	ADF&G	JRVC[a]	Weighted Mean
1.2	3.8 (24%)		4.3 (26%)
2.2	3.5 (23%)		4.0 (24%)
two-ocean	7.3 (47%)	9.6 (55%)	8.3 (50%)
1.3	5.6 (36%)		5.5 (33%)
2.3	2.7 (17%)		2.7 (17%)
three-ocean	8.3 (53%)	7.9 (45%)	8.2 (50%)
Total	15.6 (100%)	17.5 (100%)	16.5 (100%)

[a]Forecasts for individual age classes could not be made with models used.

Table 15. Synopsis of sockeye salmon returns to Bristol Bay, Alaska, river systems for age classes in which deviations of forecasted from actual returns are most likely to occur in 1987.

System	Age Class	Forecast [80% C.I.] (millions)	Summary of Indicators	Possible Deviation
Kvichak	2.2	0.429 [0.191-0.666]	Spawner-recruit prediction three and 17 times greater than sibling and smolt predictions, respectively; two-ocean returns in JRVC method greater than in ADF&G method	GREATER RETURN (upper 80% CI)
Naknek	1.2	0.236 [0.106-0.367]	No age 1.1 sockeye salmon in samples; spawner-recruit prediction over four times greater than smolt prediction; two-ocean returns in JRVC method greater than in ADF&G method	GREATER RETURN (upper 80% CI)
Egegik	1.2	1.227 [0.548-1.906]	Smolt prediction 16 and four times greater than spawner-recruit and sibling predictions, respectively; two-ocean returns in JRVC method greater than in ADF&G method	GREATER RETURN (lower 80% CI)
Ugashik	2.2	0.857 [0.383-1.332]	Smolt prediction seven times greater than sibling and 49 percent greater than spawner-recruit predictions; three-ocean ocean returns in JRVC method less than in ADF&G method	LESSER RETURN (lower 80% CI)

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Table 15. (p 2 of 3)

System	Age Class	Forecast [80% C.I.] (millions)	Summary of Indicators	Possible Deviation
Ugashik	1.3	1.265 [0.818-1.712]	Smolt prediction of 3.065 million much greater than previous record return of 2.592 million in 1986; smolt prediction eight times greater than spawner-recruit and sibling predictions; three-ocean returns in JRVC method less than in ADF&G method	LESSER RETURN (lower 80% CI)
	2.3	0.609 [0.396-0.824]	Smolt prediction of 1.099 million much greater than previous record return of 0.838 million in 1986; pooled prediction would be second largest return on record; smolt prediction two and four times greater than sibling and spawner-recruit predictions, respectively; three-ocean returns in JRVC method less than in ADF&G method	LESSER RETURN (lower 80% CI)
Wood	1.3	0.892 [0.577-1.207]	Low 1.3 return when compared with range of 1.1 to 2.4 million for past nine years; years; smolt prediction 28 and 80 percent greater than spawner-recruit and sibling predictions, respectively; three-ocean returns in JRVC method less than in ADF&G method	GREATER RETURN (upper 80% CI)
Nuyakuk	1.3	0.574 [0.371-0.777]	Sibling and smolt predictions over two times less than spawner-recruit prediction; three-ocean returns in JRVC method less than in ADF&G method	LESSER RETURN (lower 80%CI)

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Table 15. (p 3 of 3)

System	Age Class	Forecast [80% C.I.] (millions)	Summary of Indicators	Possible Deviation
Nuyakuk	2.3	0.023 [0.015-0.031]	Spawning escapement of 0.834 million second greatest recorded (record escapement of 3.026 million in 1980 produced less than one return per spawner); spawner-recruit prediction eight and 60 times greater than sibling and smolt predictions, respectively; three-ocean returns in JRVC method less than in ADF&G method	LESSER RETURN (lower 80% CI)
Togiak	2.3	0.014 [0.009-0.019]	Spawning escapement of 0.307 million second greatest recorded (record escapement of 0.526 million in 1980 produced less than one return per spawner); spawner-recruit prediction two times greater than sibling prediction; three-ocean returns in JRVC method less than in ADF&G method	LESSER RETURN (lower 80%CI)

Table 16. Forecasted returns of sockeye salmon to Bristol Bay, Alaska, river systems and commercial fishing districts 1987-1990, based only on spawner-recruit data.

	Number of Sockeye Salmon (thousands)			
District: System	1987	1988	1989	1990
Naknek-Kvichak:				
Kvichak River	2,412	5,632	12,519	8,156
Branch River	278	245	265	269
Naknek River	2,373	2,242	2,392	2,616
Total	5,063	8,119	15,176	11,041
Egegik	2,759	2,503	3,071	3,066
Ugashik	1,939	1,867	1,981	1,782
Nushagak:				
Wood River	2,128	2,055	1,893	1,779
Igushik River	653	492	487	533
Nuyakuk River	1,188	908	1,110	1,130
Total	3,969	3,455	3,490	3,442
Togiak	463	437	393	389
Total Bristol Bay	14,193	16,461	24,111	19,720

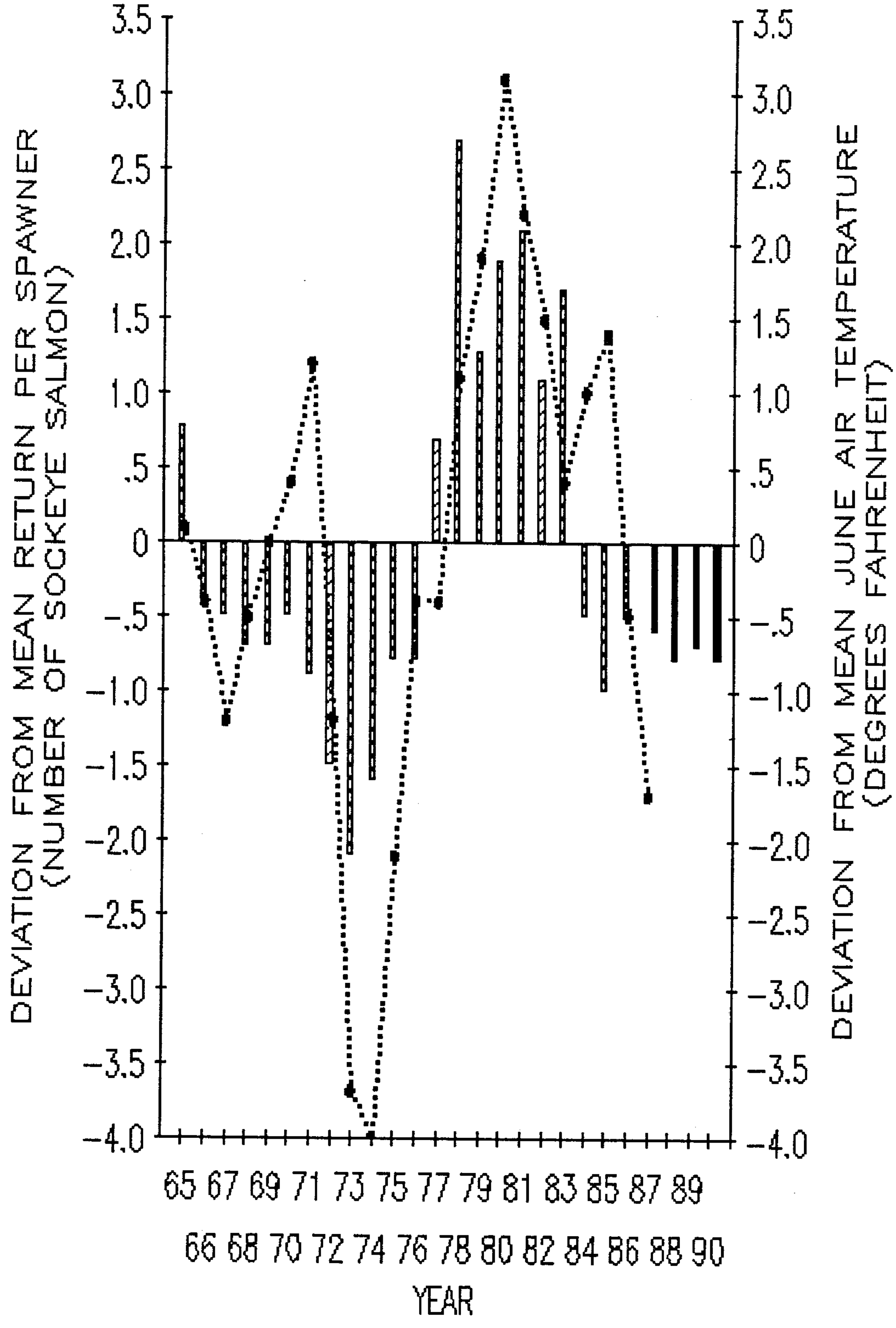

Figure 1. Annual deviations from the mean number of returning Bristol Bay, Alaska, sockeye salmon produced per spawner (bar chart) and mean Cold Bay, Alaska, June air temperature (line chart), 1965-1986. Deviations from forecasted return per spawner values are shown for 1987-1990 (solid bars).